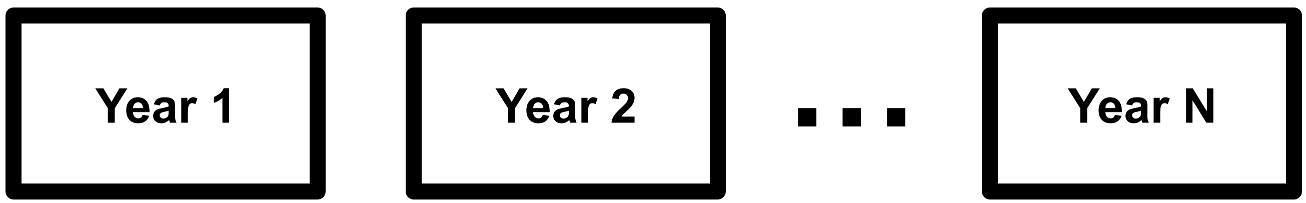
Multi-period planning models under uncertainty



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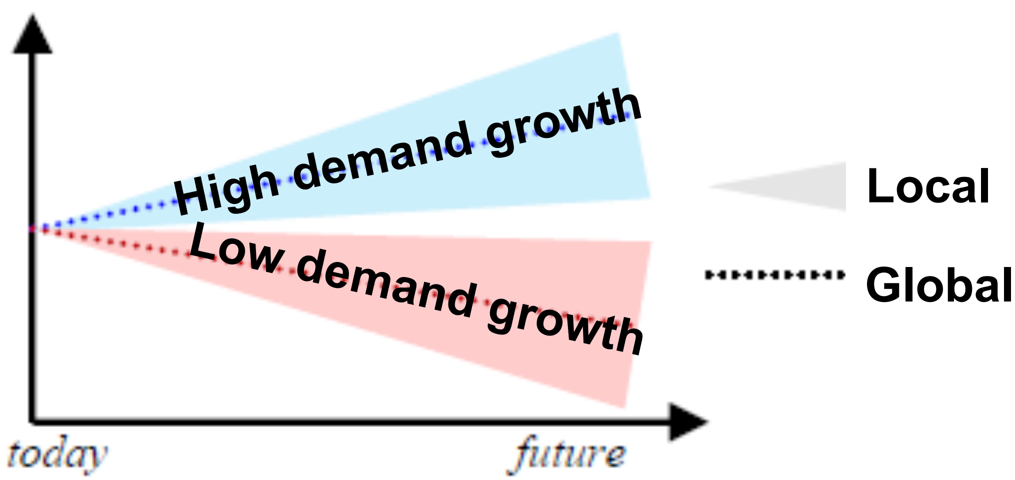
Overview

1. Types of uncertainty
   a. Local uncertainty
   b. Global uncertainty
2. Types of models
   a. Assessment models
   b. Design models
3. An assessment model: guided Monte Carlo
4. Design models
   a. For local uncertainties
   b. For global uncertainties

Types of uncertainty

a. Global - uncertainties for which different values produce dramatically different results: **emissions policies, large demand shifts, coal or nuclear unavailability, extremes in fuel prices, extended drought, dramatic change in technology investment costs.**

b. Local – uncertainty in values a parameter may take under a global realization: **variation in load growth, investment costs or fuel prices.**



Category B & C contingencies can be treated as certainties, i.e., we plan as if they will definitely occur, or they can be treated as local uncertainties, with assigned probabilities. .

Types of models

a. Assessment – these provide performance measures/indices: **Power flow, time-domain simulation, production cost, reliability evaluation (Monte Carlo, enumeration).**

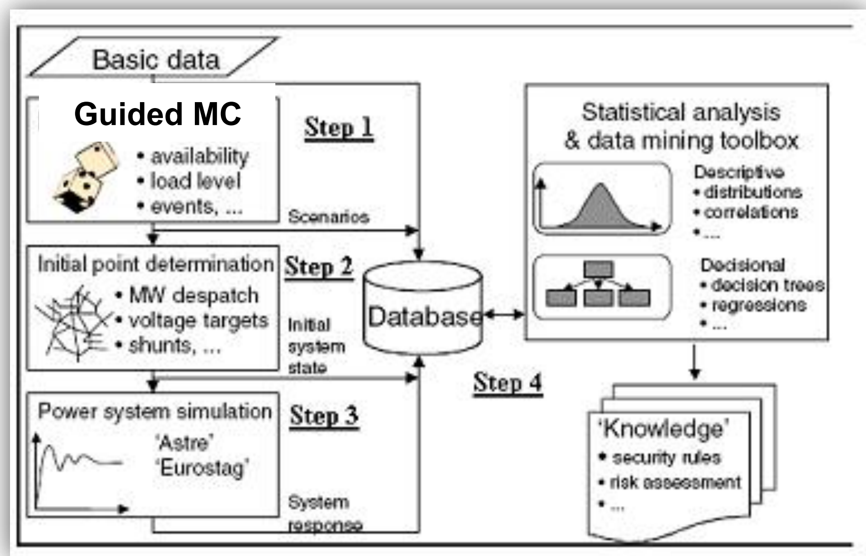
b. Decision/Design – these provide investment solutions that are "best" under the range of uncertainties: **generation expansion planning (GEP), transmission expansion planning (TEP).**

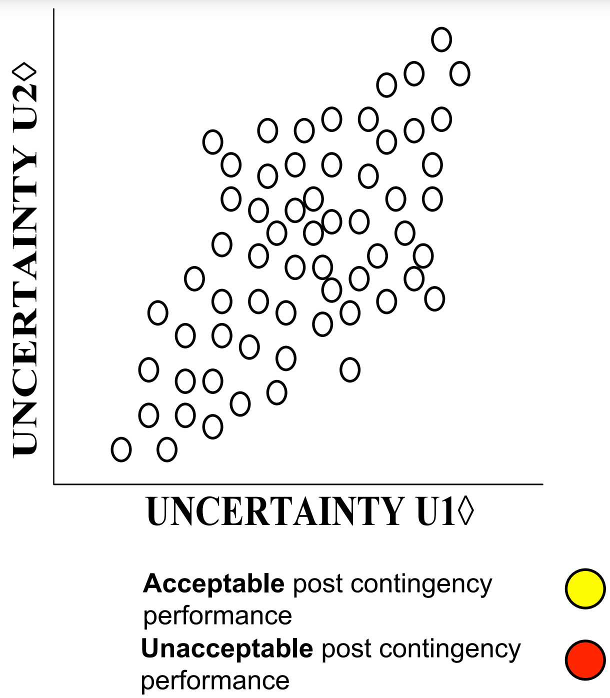
- **Decision/Design models are used for GEP (e.g., EGEAS) but very little for TEP.**
- **GEP models under uncertainty are research-grade.**
- **Deterministic TEP models are research-grade.**
- **TEP models under uncertainty under development.**

An assessment model: Guided MC

DATABASE DEVELOPMENT

1. Guided (importance) sampling
2. Optimal power flow
3. Contingency analysis



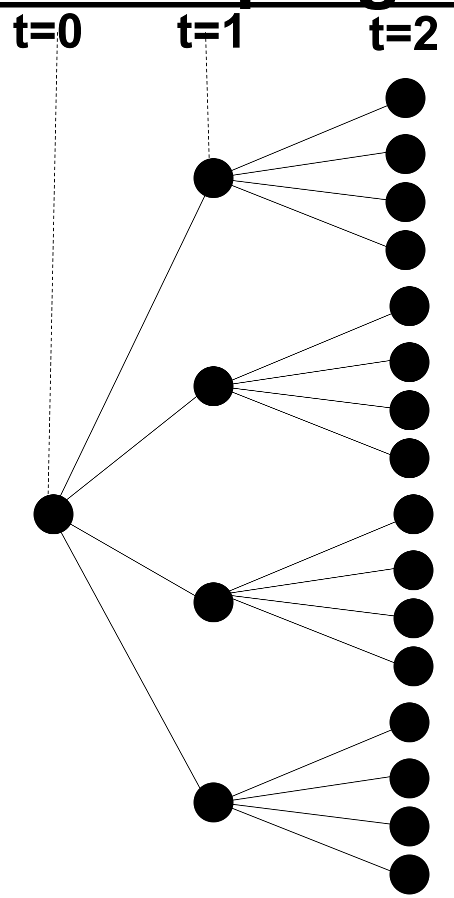


4. STATISTICAL ANALYSIS

- **Estimate** reliability indices
  - *prob(load loss)*
  - *prob(unacceptable perf)*
  - *Risk*
  - …
- Analyze Relationships
  - *Distributions*
  - *Correlations*

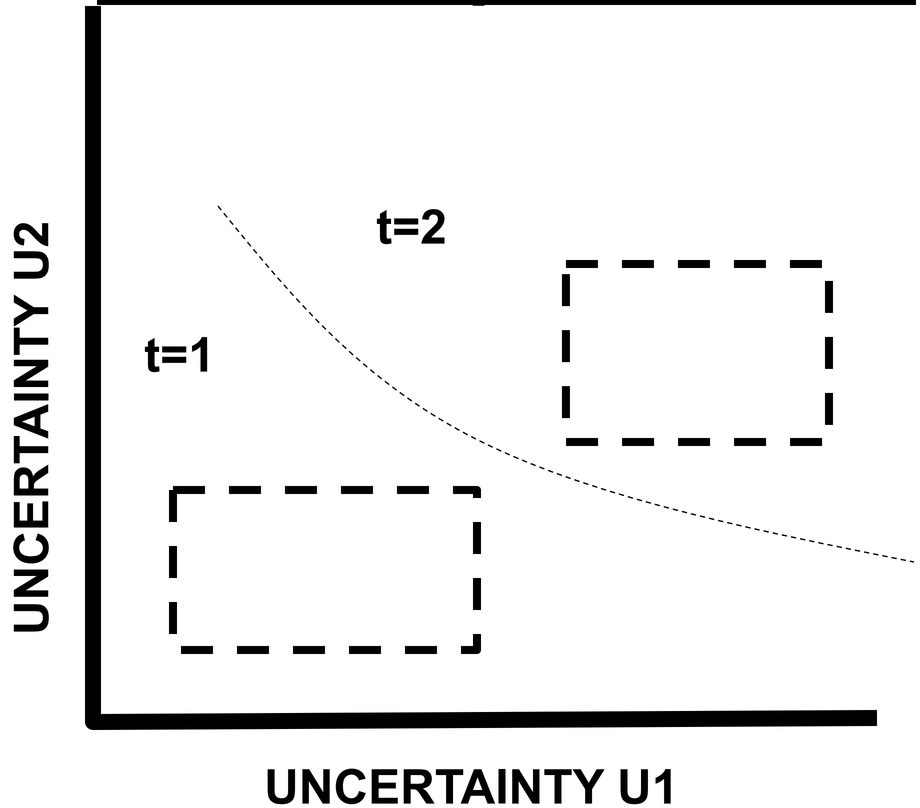
Design models for local uncertainties

Stochastic programming



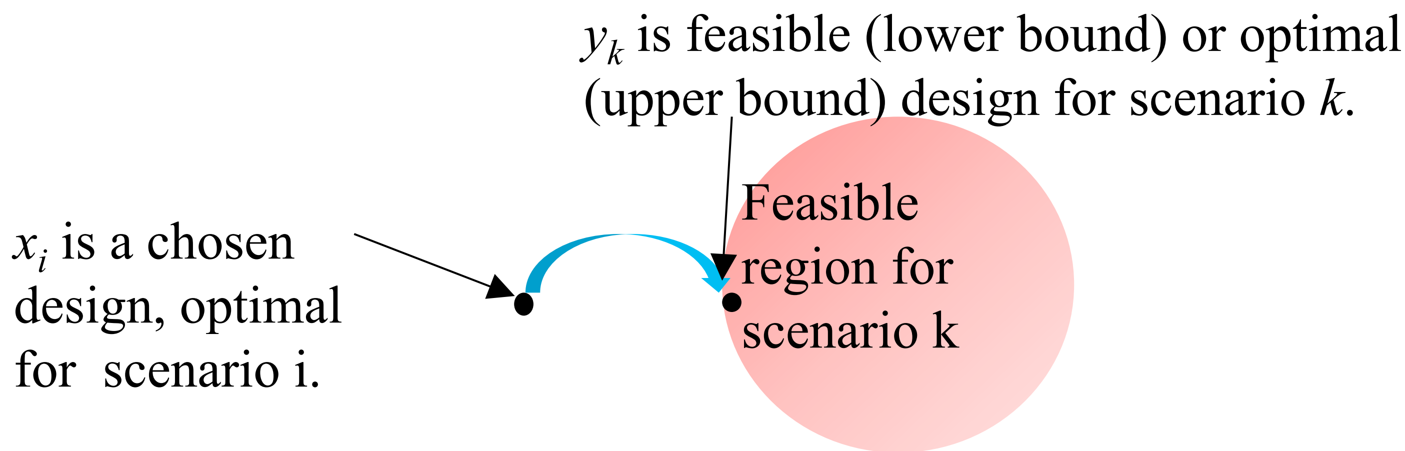
- Weaknesses: Cannot have too many uncertainties; need prob distributions.
- Strengths: Recourse counters conservatism; SP may also be applicable for global uncertainties.

Robust optimization



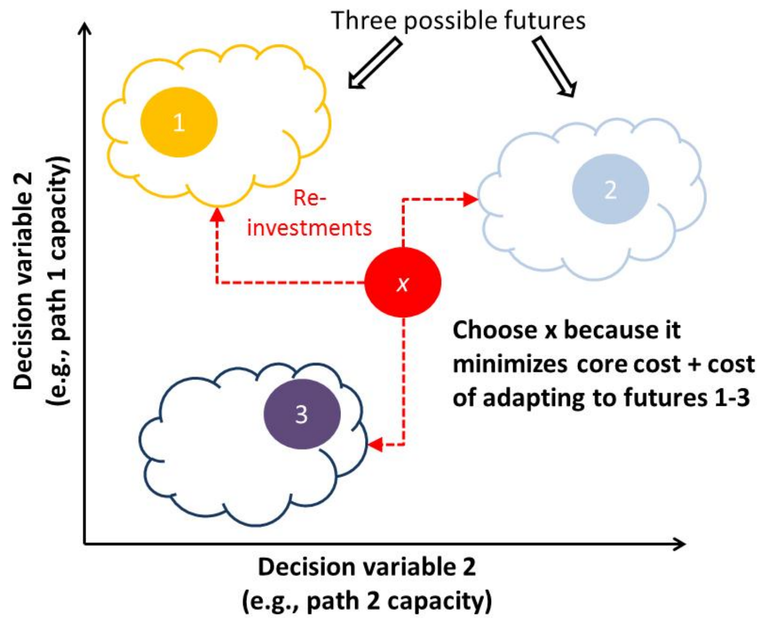
- Weaknesses: Results in solution that is feasible for entire uncertainty range and therefore conservative.
- Strengths: May be computationally more tractable. Need bounds, not prob distributions.

A <u>design</u> model for <u>global</u> uncertainty



The <u>adaptation cost</u> of x_i to scenario k is the minimum cost to move x_i to a feasible or optimal design y_k in scenario k. It measures the cost of our plan x_i if scenario k happens.

A <u>design</u> model for <u>global</u> uncertainty



Identifies an investment that is "core" in that the total "CoreCost" plus the cost of adapting it to the set of envisioned futures is minimum.

Minimize:

CoreCosts($\underline{x}^f$)+β[Σ_i AdaptationCost($\Delta\underline{x}_i$)]

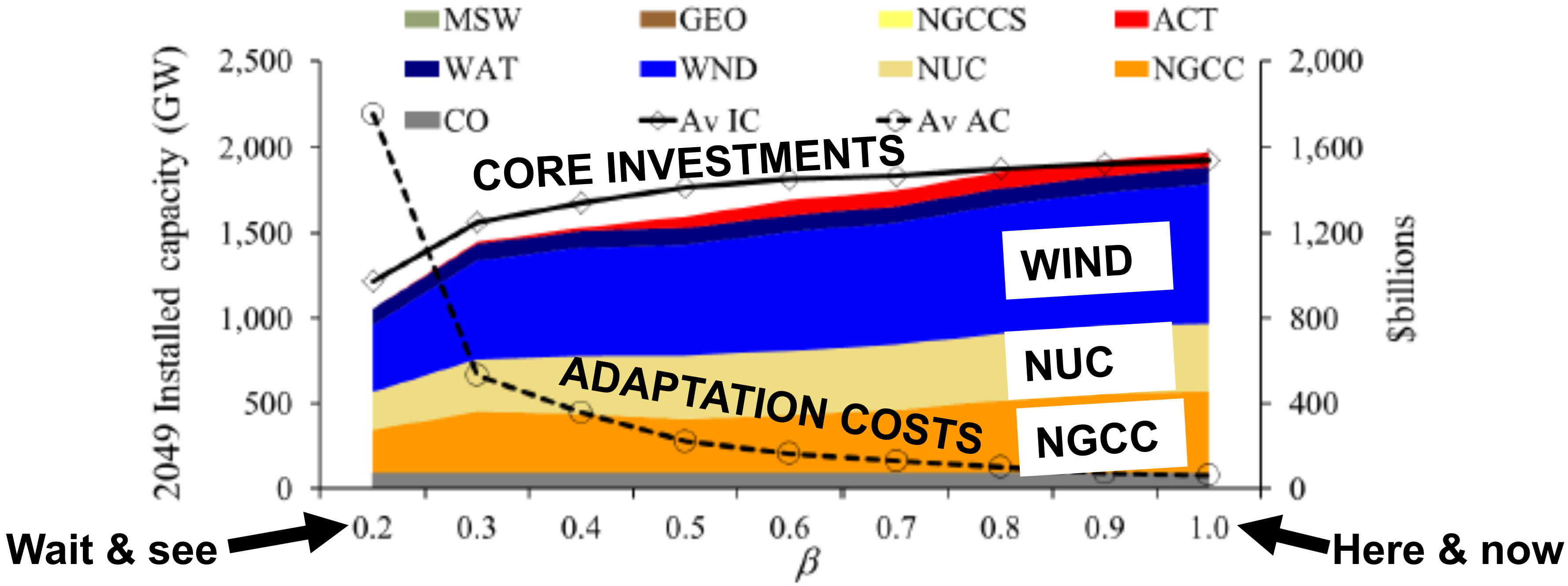
Subject to:

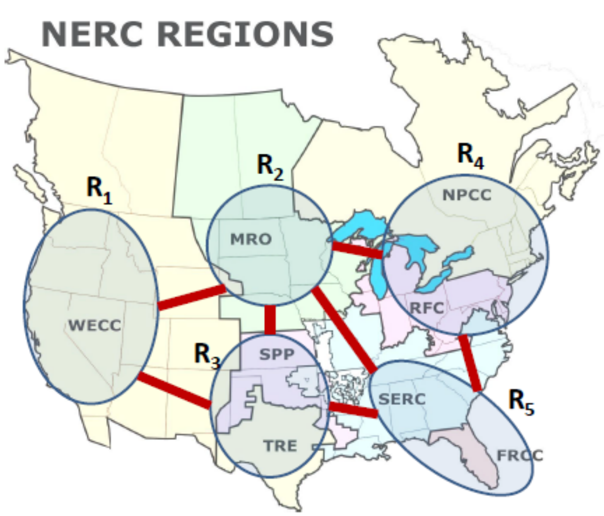
Constraints for scenario i=1,…N: $\underline{g}_i(\underline{x}^f+\Delta\underline{x}_i)\leq\underline{b}_i$

$\underline{\mathbf{x}}^{\mathbf{f}}$: Core investments, to be used by all scenarios i

$\Delta\underline{\mathbf{x}}_{\mathbf{i}}$: Additional investments needed to adapt to scenario i

A design model for global uncertainty





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CoreCosts($\underline{x}^f$)+β[Σ_i AdaptationCost($\Delta\underline{x}_i$)]

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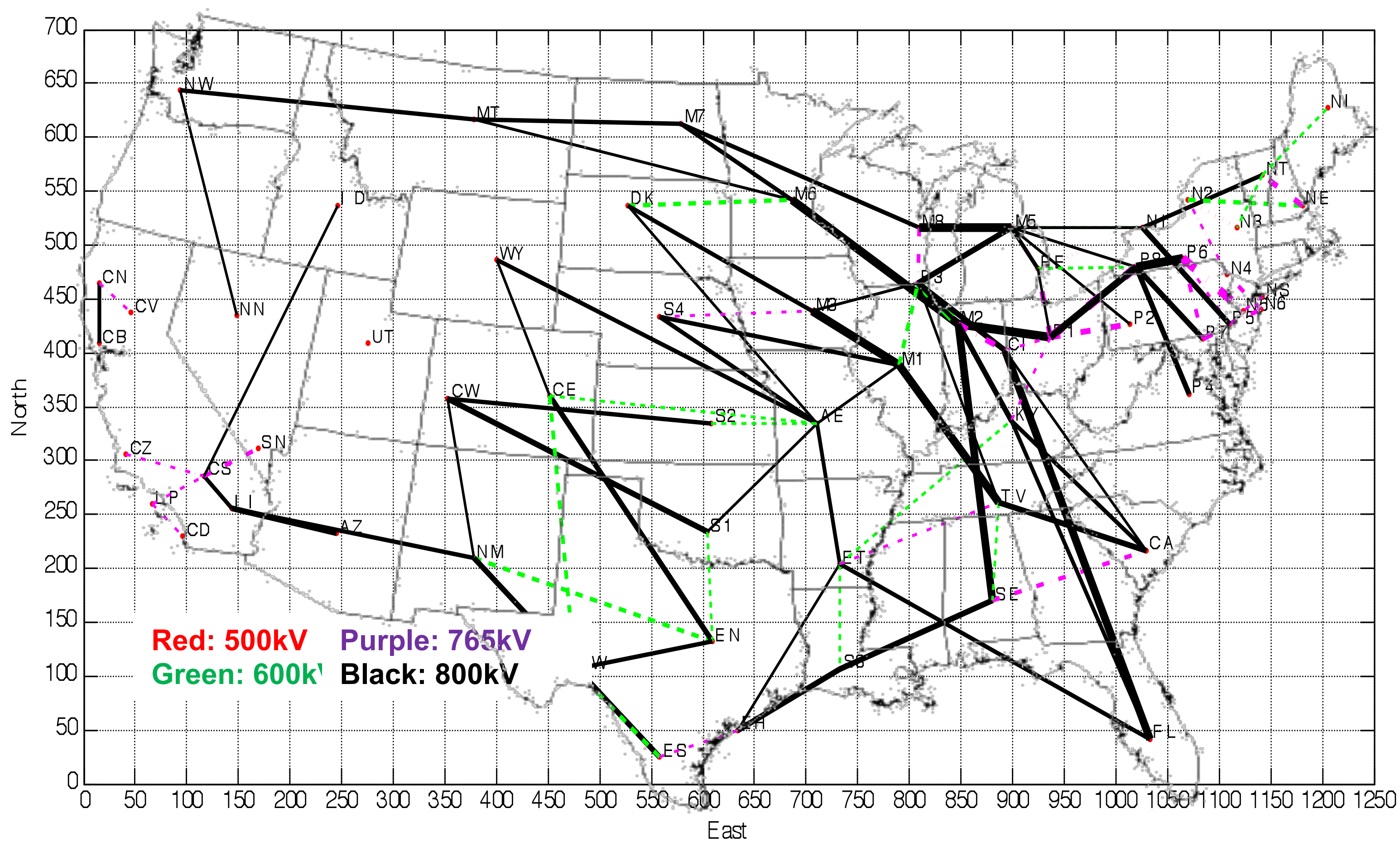
$\underline{x}^f$: Core investments, to be used by all scenarios i

$\Delta\underline{x}_i$: Additional investments needed to adapt to scenario i

Final comments

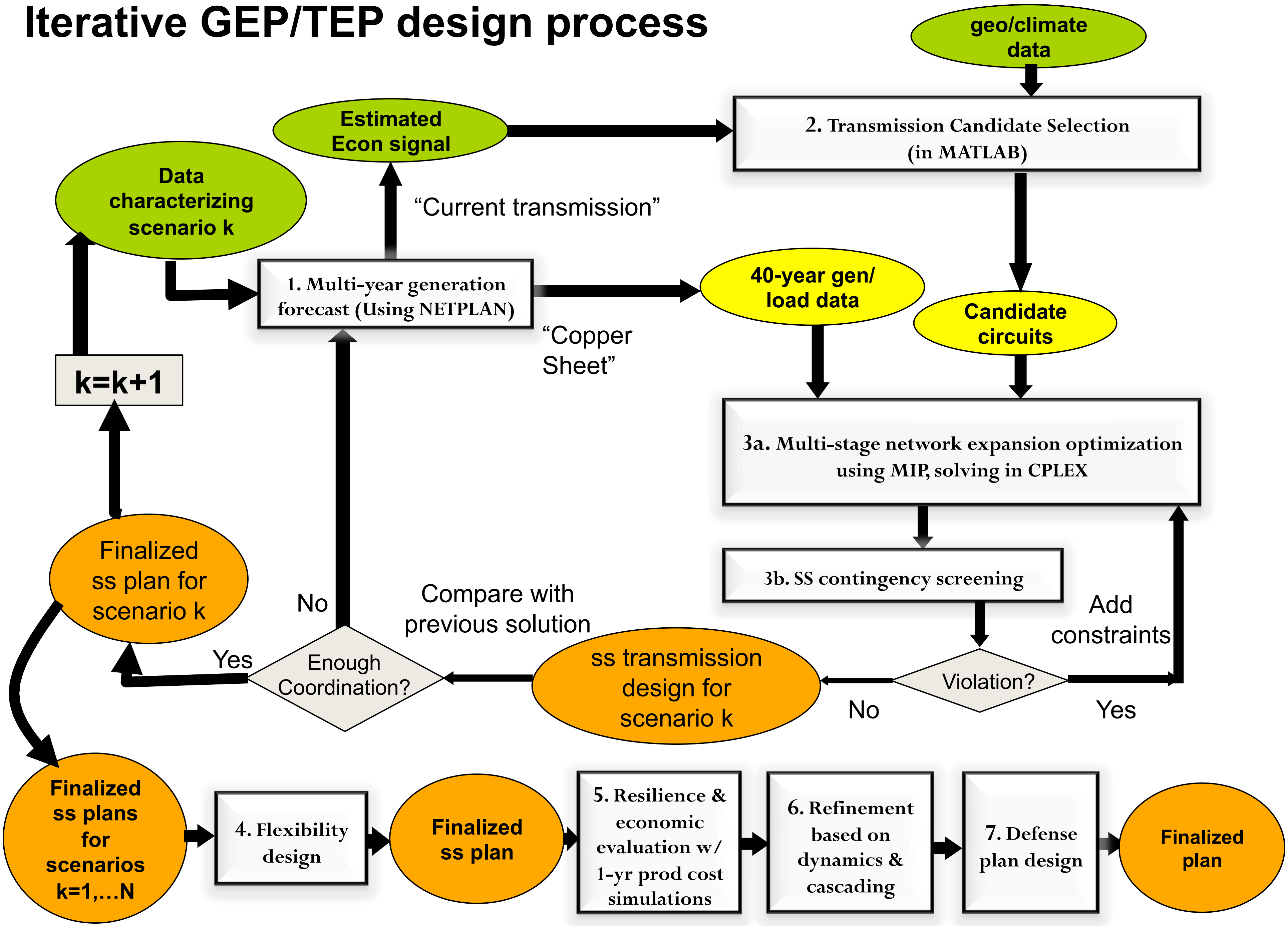
1. Tools for transmission assessment under uncertainty are available and are used.
2. Guided Monte-Carlo: a proven & effective way to harness computation for design exploration
3. Tools for deterministic transmission design are just now becoming available, but transmission design under uncertainty is a research area.
4. Local uncertainties: addressed by SP and RO.
5. Global uncertainties: Design for flexibility!
6. SP, RO, and Flexibility design needs resources to be developed into commercial tools.

A deterministic TEP result



A renewable-heavy generation portfolio, with particular emphasis on wind in the Midwest and Northwest and geothermal in the West.

Iterative GEP/TEP design process



Scenarios used in flexibility design

Cluster	GP Gas price	GPL Gas production limits	D Demand	RPS	CO_2^{cap}	WC Wind investment cost
Benchmark	L	No	L	No	No	H
1	L	No	L	No	No	L
2	L	No	L	Yes	No	H
3	L	No	L	Yes	Yes	L
4	L	No	H	No	Yes	H
5	L	Yes	L	Yes	Yes	H
6	H	No	L	Yes	Yes	L
7	H	No	H	No	Yes	L
8	H	Yes	L	No	No	L
9	H	Yes	L	Yes	Yes	H
10	H	Yes	H	Yes	No	H